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PRELIMINARY ASSESSMENT OF THE PREVALENCE OF CYAMID "WHALE LICE" (*CYAMUS CETI*) ON SUBSISTENCE HARVESTED BOWHEAD WHALES (*BALAENA MYSTICETUS*)

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Abstract

We present preliminary findings of the prevalence and abundance of the ectoparasite cyamid *Cyamus ceti* or "whale lice" on bowhead whales harvested for subsistence purposes from 1973 to 2014. There was a 20% prevalence of cyamids on the 645 bowhead whales examined for ectoparasites. We assessed several logistic regression models to determine factors associated with cyamid prevalence. Of the 134 whales that were examined for ectoparasites and which had an age estimate, the probability of cyamid presence increased with age. When present, cyamids typically occurred in low numbers (< 10 per whale). Several case histories provide ancillary information about the relationships between cyamid abundance and their bowhead hosts. Considering anticipated changes to arctic regions inhabited by bowhead whales, variability in the prevalence and/or intensity of cyamids may serve as a bio-indicator of change in bowhead whale health and/or environmental conditions.

Introduction

Cyamids or "whale lice" are ectoparasite crustaceans (Order: Amphipoda) that feed on the epidermis of their host and are common to many cetacean species (Schell et al. 2000). Evidence from long-term visual health assessments suggests that the spatial distribution and abundance of cyamids on North Atlantic right whales (NARW; *Eubaleana glacialis*) is related to the host's health and body-condition. For example, orange cyamids (*Cyamus erraticus*) are rare on healthy adult NARWs (R. Rolland *pers. comm.* 2015), and their presence has been associated with poor health and/or body-condition (Schick et al. 2013; Pettis et al. 2004). Pettis et al. (2004) observed infestations of cyamids on NARWs in "last-sighting" photos, after which the whales were presumed dead. Additionally, a NARW entangled by a line around its rostrum that prevented feeding became almost entirely covered with cyamids before its eventual death from starvation (Rosalind Rolland, M. Moore *pers. comm.*; Moore et al. 2006). Reduced swimming speed in physically compromised whales presumably allows cyamids a more favorable environment upon which to attach and "hang on" (Rowntree 1996).

Bowhead whales (*Balaena mysticetus*) are one of four species in the Family Baleanidae and are closely related to Right whales (*Eubaleana spp.*). Unlike NARWs, the Bering-Chukchi-Beaufort seas (BCB) stock of bowheads is currently increasing in population (Givens et al., 2013) and experiences much lower levels of anthropogenic maritime disturbance (Kraus and Rolland 2007). While cyamid presence on NARWs has been studied (Pettis et al. 2004), this work presents, to our knowledge, the first examination of the prevalence and intensity of cyamid occurrence on bowhead whales. Bowhead whales are long-lived, have a slow reproductive rate, and have evolved a strategy of "weathering" environmental variability (George et al 1999; Burns, 1993). Consequently, they may show a "dampened" response to large environmental perturbations. An understanding of cyamid-bowhead relationships may be useful as change in

the prevalence and/or abundance of cyamids on harvested bowheads may indicate a shift in the relative health of bowheads and/or the marine ecosystem.

Our objective was to characterize the relationships between cyamid prevalence and intensity with respect to overall condition, morphology, and demography of bowhead whales. Drawing from the harvest records of BCB bowhead whales that were hunted for subsistence purposes by Alaska Natives, we compiled and analyzed data from all whales that were visually inspected for cyamids. We present preliminary findings and baseline information on the prevalence and intensity of cyamid whale lice on BCB bowheads.

Methods

In cooperation with the Alaska Eskimo Whaling Commission (AEWC) and village Whaling Captains' Associations, harvested bowhead whales have been examined by the National Marine Fisheries Service (NMFS) in the 1970s and by the North Slope Borough Department of Wildlife Management (NSB) from the early 1980s to present. When possible, visual examinations which documented the presence and location of cyamids were conducted on harvested bowheads immediately upon landing of the carcass and prior to its processing.

Morphometric and biological data collected from each whale that was examined for cyamids was used to assess several logistic regression models. The response variable for these models was the probability that cyamids were present [P(cyamid presence)]. Several explanatory variables were considered, including the whale's total length (*LEN*), age (*AGE*), and sex (*SEX*). Detailed descriptions of the methods used to collect these data can be found in George (2009). We also considered the whale's body-condition (*COND*) as an explanatory variable. We characterized *COND* using the residuals from the following linear regression:

$$GIRTH_{axillary} = 124.492 + 55.856 \cdot LENGTH_{body} \qquad R^2 = 0.88$$

The sign and magnitude of the residuals from this model indicate whether a whale is fatter or thinner than predicted for its length and provide an indicator of body condition. Whale age (*AGE*) was estimated *via* several methods including annual carbon cycles in the baleen (Lubetkin et al. 2008), aspartic acid racemization of eye lens tissue (George et al. 1999), and/or by corpora accumulation (George et al 2012) in the ovaries. We also considered three interactions: *AGE:SEX*, *COND:SEX*, and *AGE:COND*. We did not assess models that contained both *LEN* and *AGE*, because these covariates were highly correlated ($t = 13.6$, $df = 124$, p-value $< 2.2e^{-16}$). Temporal patterns in cyamid presence were assessed *via* lagged correlations between the percent of whales with cyamids and the year of harvest. Model performance was assessed based on AIC_C, where the highest performing models had the lowest values of ΔAIC_C. All statistical analyses were conducted in program R (R Core Team 2014).

Results

We compiled records from 645 harvested bowhead whales that were examined for ectoparasites. A total of 129 (20%) of the examined whales had at least one cyamid noted. Of the bowheads with cyamids present, 69% had 1 - 5 cyamids (Figure 1, Class 1) present, whereas the remaining 31% had 6 or more cyamids (Figure 1, Classes 2 & 3). Because whales typically had less than 10 cyamids present, absolute cyamid abundance was not formally analyzed. However, a review of selected case histories provides ancillary information concerning the relationship between cyamid abundance and bowhead body-condition (Table 1).

Our models were based on data taken from whales that were examined for ectoparasites and which had an age estimate (n = 134). The three highest ranking logistic regression models (Table 2), all of which include *AGE* as a covariate, exhibited comparable performance (i.e. $\Delta AIC_C \leq 2.0$). The highest ranking model ($\Delta AIC_C = 0$) contains *AGE* as its only variable, and suggests that older whales have a higher probability of cyamid presence. The second best model ($\Delta AIC_C = 1.63$) includes both *AGE* and *COND*, and suggests that, if *AGE* is held constant, whales that are fatter than predicted (i.e. in "good" body condition) are more likely to have cyamids. The third best model ($\Delta AIC_C = 1.77$) includes both *AGE* and *SEX*, and suggests that if age is held constant, females tend to have a higher probability of cyamid presence. No other models were comparable in performance (i.e. $\Delta AIC_C > 2.0$). No significant difference in the frequency of whales with cyamids was identified among the villages where harvested whales were sampled ($X^2 = 3.3$, d.f. = 4, $p = 0.51$). We observed a pattern that suggests periodicity in the frequency of cyamid occurrence (Figure 2). An autocorrelation plot (Figure 3) suggests negative temporal autocorrelation that peaks every two or three years, but this was not statistically significant ($X^2 = 32.8$, d.f. = 24, $p = 0.11$).

Body-condition was present in the second best model (Table 2), but the sign of the coefficient indicates that P(cyamid presence) increases as body-condition improves (an opposite trend to the NARW). While our model results indicate that the *prevalence* of cyamids on BCB bowhead whales was not related to poor body-condition, a review of selected case histories (Figure 1) provides some evidence that cyamid *abundance* is related to poor body-condition. For example, of whales with more than 10 cyamids present (Figure 1, Class 3, n = 26), nine (34.6%) had old traumatic injuries, scarring, and/or damaged skin. However, it is also interesting to note that one of these whales (99B14, Table 1), despite heavy line entanglement and poor physical condition, did not have cyamids present. Meanwhile, whale age was strongly positively related to P(cyamid presence). For example, one of the oldest whales in our database (95B9; male; estimated age = 174; Table 1) was described as having "lots of lice". Nevertheless, there were notable exceptions in our database (Table 1), including a young female (04B3; estimated age ~1 year; Table 1) that had approximately 100 cyamids present, and four other heavily infested whales that were not yet sexually mature (i.e. < 14 meters long; see Nerini et al. 1984).

Discussion

Our preliminary assessment determined that cyamids were present on 20% of those harvested bowhead whales that were examined for ectoparasites. When present on a whale, cyamids occurred in relatively low numbers (e.g. typically less than 10 cyamids per whale). The variable *AGE* was featured in all of the top models and was highly significant (p-value < 0.001). Given that (1) there is no aquatic stage for cyamids (Rowntree 1996), (2) direct contact is the primary route of cyamid acquisition, and (3) the longevity of the bowhead whale, it is plausible that older whales should have more opportunities to obtain cyamids through exposure over time. While from an epidemiological perspective, 20% prevalence of whales with cyamids is considered "common," our study does not conclude that the cyamind prevalence is biologically significant, especially due to the typically low absolute cyamid abundance per individual whale. Because cyamid abundance per whale is typically low, opportunities for whale to whale transmission may also be low. This may partially explain how it is possible that a bowhead whale of very compromised health (99B14, Table 1) over a long time period showed no cyamids present (i.e. cyamids were not present on this whale to proliferate).

While cyamid *prevalence* was not related to a decline in bowhead whale body condition, evidence from selected case studies (Table 1) suggests that cyamid *abundance* may in some cases indicate an individual animal's health. For example, a bowhead "covered" in cyamids such as 08G1 is quite unusual and is probably an animal in poor health. However, this was not always the case, as we also observed bowheads in poor body condition with no cyamids present.

Climate change is affecting the marine ecology of the regions inhabited by BCB bowhead whales, and it is anticipated these trends will continue (Moore et al 2014; Moore and Laidre 2006). Increased maritime shipping and industrial development in response to declining sea ice (Reeves et al. 2012) may also lead to increased anthropogenic maritime disturbance levels. Both outcomes may eventually have a negative effect upon the health of the BCB bowhead whale population. While the current level of cyamid prevalence in this population is "common", at present, cyamid abundance per whale is below levels associated with poor health in NARWs. Furthermore, other components of bowhead health assessments indicate that this population is very healthy with few incidental findings (Willetto et al., 2002; Philo et al., 1993). Bowhead whale health and physiology workshop, October 2001. North Slope Borough, Department of Wildlife Management, Barrow, Alaska. 129 pp.). We suggest that monitoring these parameters within the context of ongoing changes in the Arctic may at some point be a useful bio-indicator of the health of BCB bowhead whales and enhance a comprehensive program of arctic ecosystem assessment (Moore and Gulland 2014).

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Tables

Table 1: Selected case studies of bowhead whales harvested in Alaskan waters. Whales are listed in chronological order beginning with the most recent.

*no age estimate
ingutuk = 1.5 to 2.5 years of age

ID	Year	Sex	Length (m)	Age (yrs)	Cyamid abundance
14B4	2014	Male	9.0	*	Higher than normal
Notes Recovered dead in the spring lead at Barrow. This whale was struck and lost near Wainwright (~ 190 km southwest of Barrow) and drifted north over a period of about 4 days. Many cyamids were seen scattered over the body, on the flukes, peduncle, and head. These cyamids ranged in size from 0.5 cm to 2.0 cm. What is particularly interesting about this case is that the whale was only adrift for four days, but this appeared to be sufficient time for the cyamids to proliferate.					

ID	Year	Sex	Length (m)	Age (yrs)	Cyamid abundance
08G1	2008	Male	14.3	*	Heavily infested
Notes Landed at Saint Lawrence Island. Biologists were not present but the Captain related the following observations to Sheffield: *Numerous large patches of cyamids on skin of lower body and genital slit. Black skin [epidermis] was reported as thin and the maktak tough. Large patches of cyamids on the middle lower portion of the body and genital slit. The hunters noted the whale had two 5 cm diameter circular "swollen" scars on dorsal region ~25-30 cm 3 to 4 meters anterior to peduncle. When first spotted, the whale was not swimming and repeatedly dove and surfaced in one place and was "oblivious to the approach" of the whaling crew. The whale acted normally when struck and dove, taking down two floats. But it "swam at a slow pace."* Based on the Captain's description this bowhead was physically compromised and behaved abnormally.					

ID	Year	Sex	Length (m)	Age (yrs)	Cyamid abundance
04B3	2004	Female	9.1	*Ingutuk (likely 1 year)*	About 100
Notes Whale lice, near eye and along mouth ~100 in 2 groups (at least).					

ID	Year	Sex	Length (m)	Age (yrs)	Cyamid abundance
99B14	1999	Male	14.2	63.7	None reported
Notes Severely entangled in crab lines through the mouth and around the peduncle. Considered to be in poor condition, with severe lacerations and gray skin. Blubber 'froze' during butchering. The examiners did <u>not</u> report cyamids on this animal. We reexamined photographs of 99B14 and did not see cyamids. This is inconsistent with observations on compromised NARWs;					

ID	Year	Sex	Length (m)	Age (yrs)	Cyamid abundance
95B9	1995	Male	17.5	172	Lots of "lice"
Notes Whale 95B9 was the largest male measured at Barrow in our database and also among the oldest whales recorded. It was described as having "lots of lice". Described as having areas of the vertebral column that had spondylosis. This has not been described in other BCB bowhead (Paul Nader, pers. comm.)					

Table 2: Ranked logistic regression models in which the response variable is the probability of cyamid presence. Explanatory variables are shown in the column headers. These models were generated from whales harvested on the North Slope of Alaska that were examined for cyamids and that had an age estimate (n = 134). *AGE* is the estimated age of the whale (see methods). An index of body-condition (*COND*) is defined as the residuals from a linear regression model of the form [$GIRTH_{axillary} = 124.492 + 55.856 \cdot LENGTH_{body}$; $R^2 = 0.88$]. *SEX* is in indicator variable where females = 1 and males = 0. Bold highlighted models indicate $\Delta AIC_C < 2.0$.

Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05 '•' 0.1

			Coefficient (SE)						
ID	**AIC_C**	**ΔAIC_C**	***LENGTH***	***COND***	***AGE***	***SEX***	***AGE:SEX***	***COND:SEX***	***AGE:COND***
1	**115.08**	**0.00**	--	--	**0.02** (0.007)**	**--**	**--**	**--**	**--**
2	**116.71**	**1.63**	--	**0.003 (0.004)**	**0.02** (0.007)**	--	--	--	--
3	**116.85**	**1.77**	--	**--**	**0.02** (0.007)**	**0.29 (0.51)**	**--**	**--**	**--**
4	118.59	3.51	--	$5.8e^{-4}$ (0.006)	0.02** (0.008)	--	--	--	$5.8e^{-5}$ ($1.2e^{-4}$)
5	118.59	3.51	--	0.002 (0.003)	0.02** (0.008)	0.26 (0.52)	--	--	--
6	118.92	3.84	--	--	0.02* (0.009)	0.17 (0.72)	0.004 (0.02)	--	--
7	121.81	6.73	0.18* (0.08)	--	--	--	--	--	--
8	123.21	8.13	0.17* (0.08)	0.003 (0.004)	--	--	--	--	--
9	126.05	10.97	--	0.003 (0.004)	--	--	--	--	--
10	126.78	11.69	--	--	--	0.07 (0.47)	--	--	--
11	128.32	13.24	--	-0.004 (0.006)	--	0.02 (0.49)	--	0.01 (0.008)	--

Figures

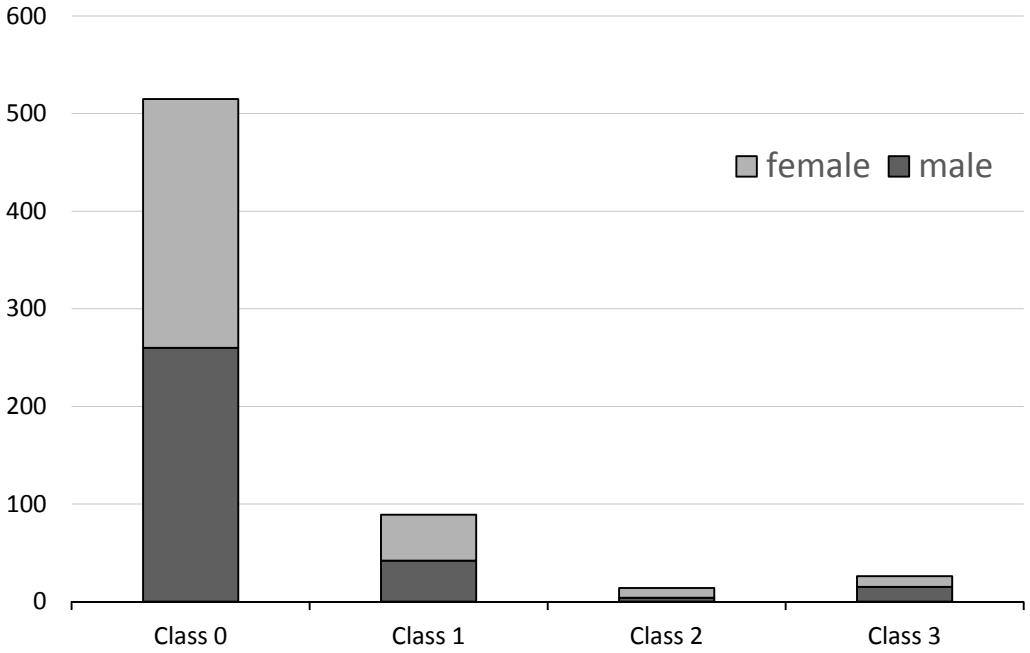

Figure 1: Histogram of bowhead whales examined for cyamids (n = 645). Note that there was no significant difference in the frequency of cyamid presence by sex ($X^2 = 3.51$, df = 3, p-value = 0.32). Classes indicate the number of cyamids detected on harvested whales during gross examination immediately upon landing. Class 0: none detected, Class 1: 1 to 5 cyamids detected, Class 2: 6 to 10 cyamids detected, and Class 3: more than 10 cyamids detected. Categorical data were scored from observer comments on the bowhead whale harvest data forms.

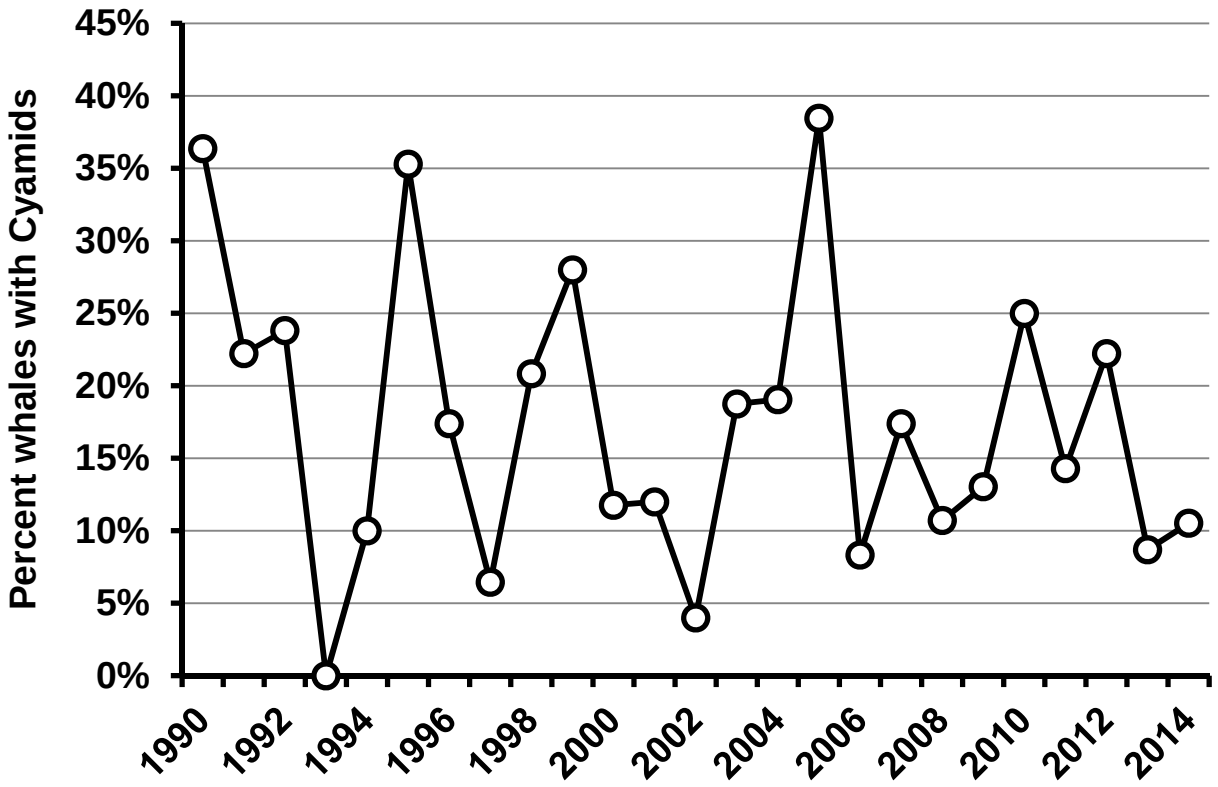

Figure 2: Percentage of harvested whales with cyamids present, by year. Cyamid presence appears to follow a three to four year cycle; however, autocorrelation analysis suggests this pattern is not statistically significant.

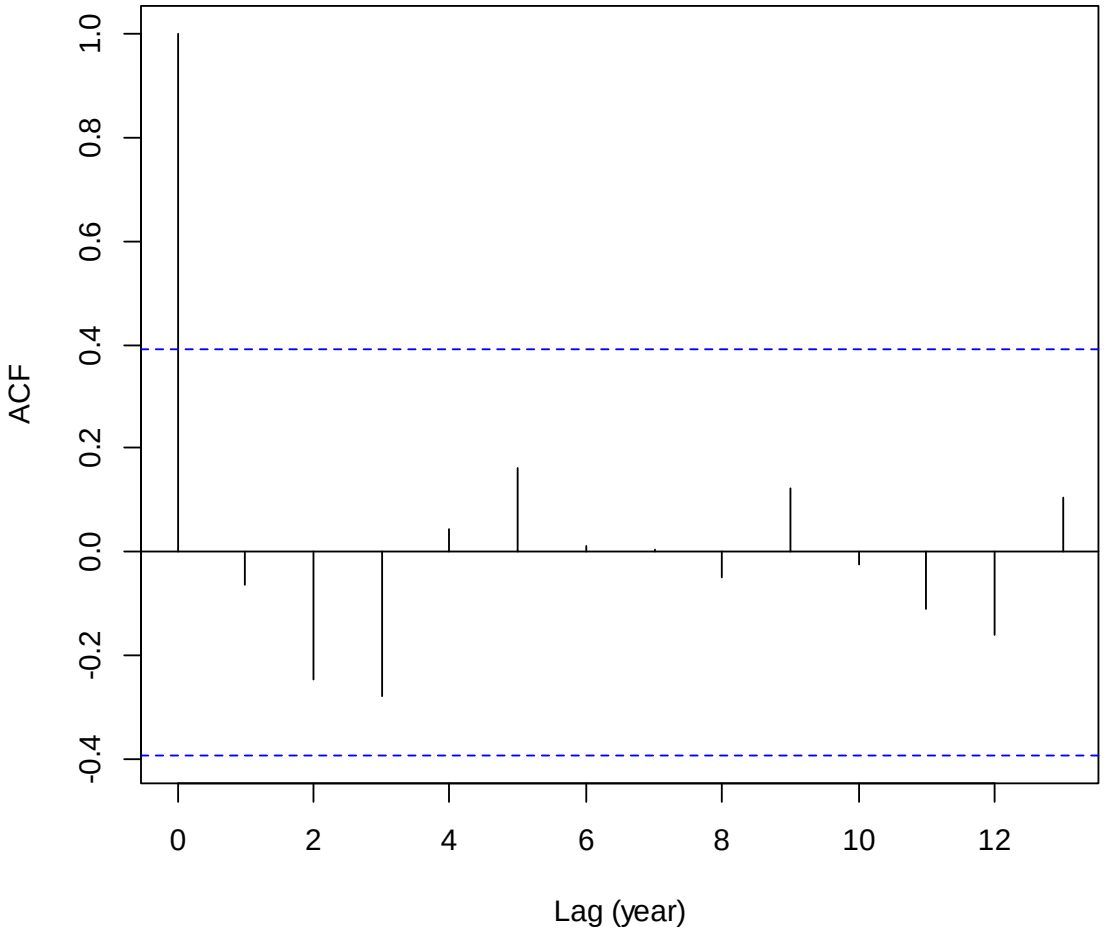

Figure 3: **T**emporal autocorrelation in the percentage of harvested whales with cyamids. While there appears to be a negative correlation every 2 or 3 years, it is not statistically significant (i.e. the vertical bars at lags 2 and 3 do not cross the horizontal dashed line).

Figure 4: A bowhead whale harvested in Gambell on Saint Lawrence Island during 2008 (ID 08G1) infested with extensive large patches of orange colored cyamids over large areas of its body (Photo: M. Koonooka).